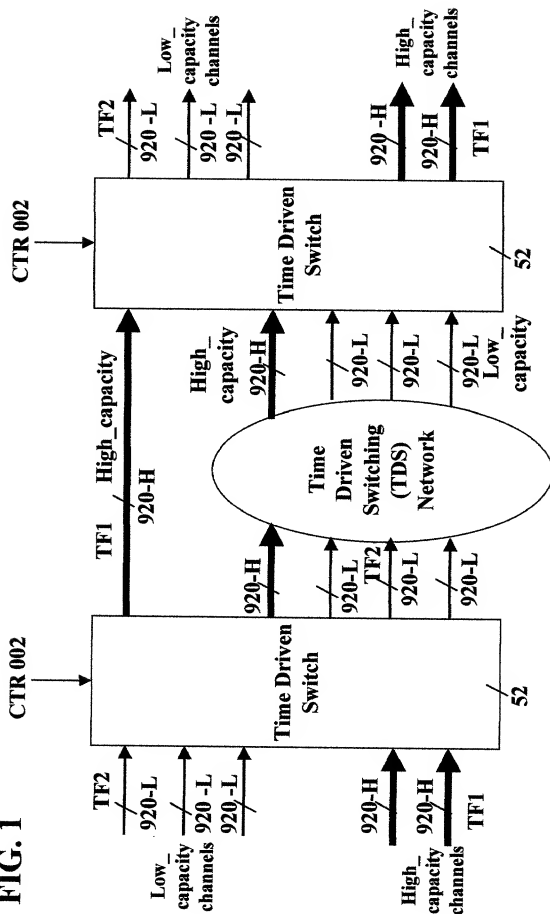


FIG. 1



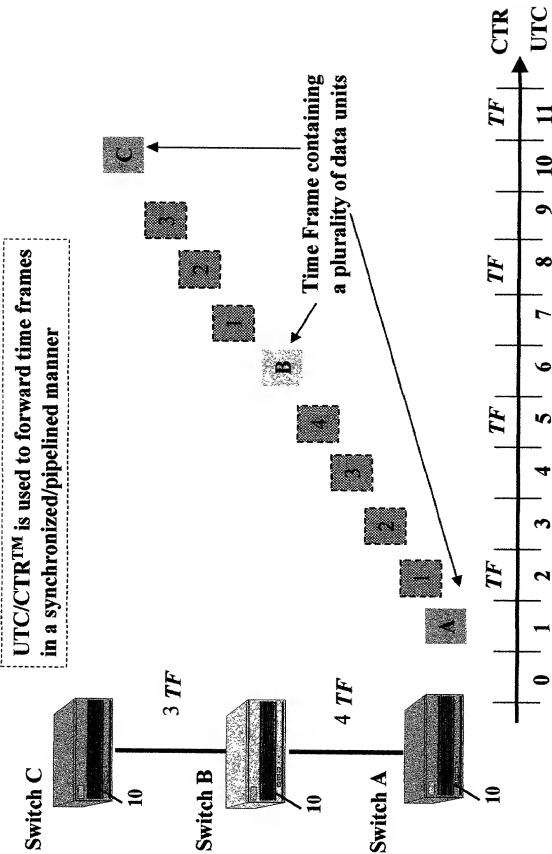
$$\begin{aligned} \text{TF1} &= 15.325 \text{ microsec} - \text{High_capacity} = \text{OC-192} \\ \text{TF2} &= 125 \text{ microsec} - \text{Low_capacity} = \text{OC-3} \\ &\Rightarrow c = 64 = (\text{OC-192}/\text{OC-3}) \end{aligned}$$


**beginning
of a UTC second**

beginning of a UTC second

CTR (UTC)

FIG. 3



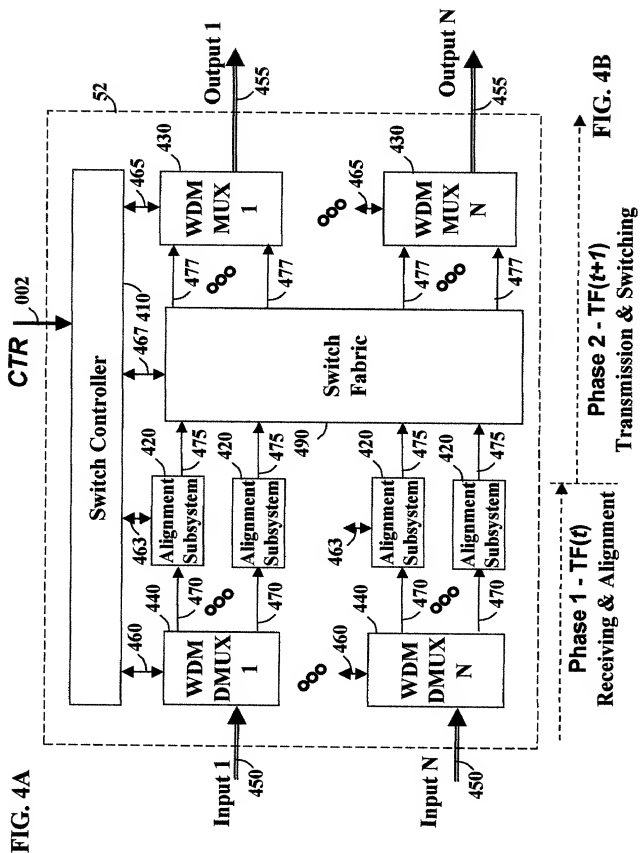


FIG. 5

Two time intervals: $SC1_length \cdot TF1 = 1$ UTC second

- $SC2_length \cdot TF2 = 1$ UTC second

- $TF2 = (SC1_length / SC2_length) \cdot TF1 = k \cdot TF1$, where the time cycles of TF1 and TF2 are aligned with respect to UTC.

For $k = 2$ and $c = 4$ (e.g., $High_capacity = OC-192$, $Low_capacity = OC-48$):

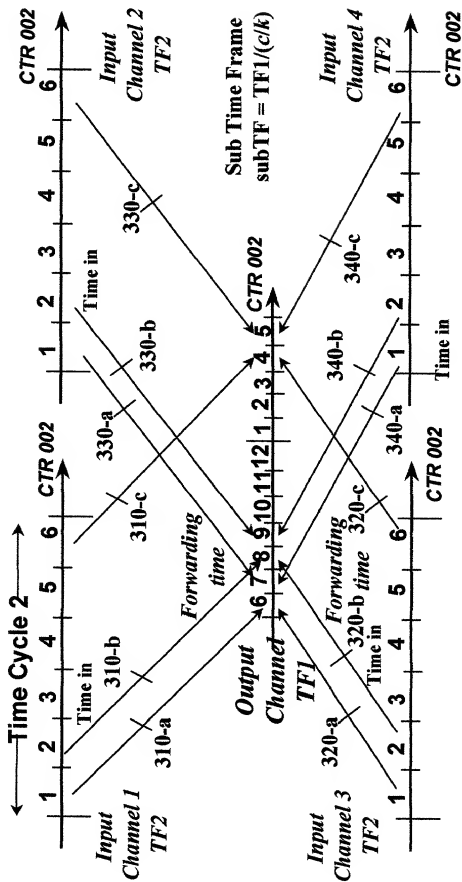


FIG. 6 Two time intervals: $SC1_length \cdot TF1 = 1$ UTC second

- $SC2_length \cdot TF2 = 1$ UTC second
- $TF2 = (SC1_length / SC2_length) \cdot TF1 = k \cdot TF1$, where the time cycles of $TF1$ and $TF2$ are aligned with respect to UTC.

For $k = 2$ and $c = 4$ (e.g., $High_capacity = OC-192$, $Low_capacity = OC-48$):

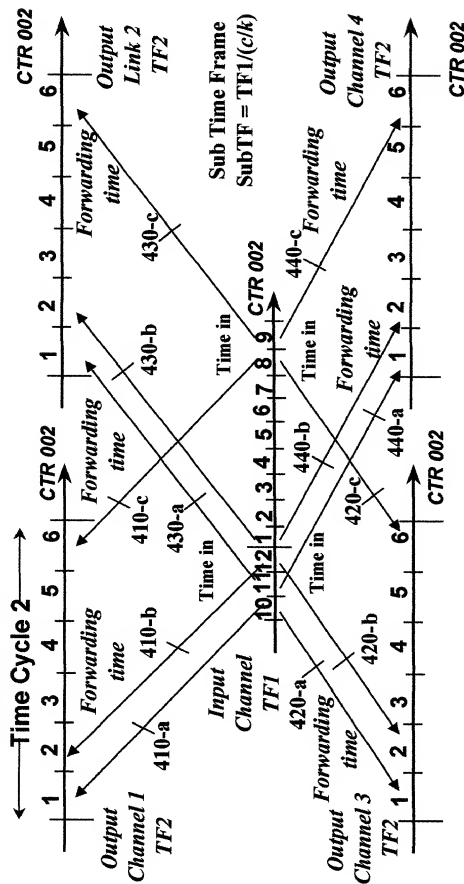


FIG. 7

Two time intervals: $SC1_length \cdot TF1 = 1$ UTC second

- $SC2_length \cdot TF2 = 1$ UTC second

- $TF2 = (SC1_length / SC2_length) \cdot TF1 = k \cdot TF1$, where the time cycles of $TF1$ and $TF2$ are aligned with respect to UTC.

For $k = 2$ and $c = 4$ (e.g., High_capacity=OC-192, Low_capacity=OC-48):

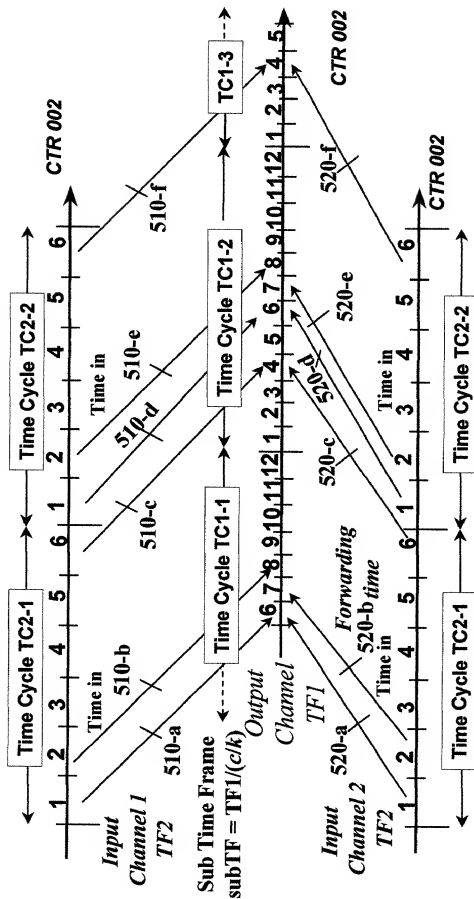
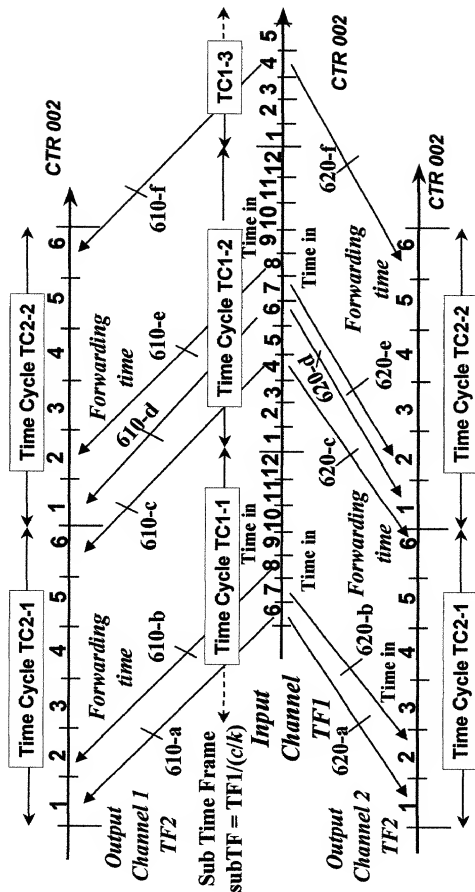


FIG. 8

- Two time intervals: $SC1_length \cdot TF1 = 1$ UTC second
- $SC2_length \cdot TF2 = 1$ UTC second
 - $TF2 = (SC1_length / SC2_length) \cdot TF1 = k \cdot TF1$, where the time cycles of $TF1$ and $TF2$ are aligned with respect to UTC.
- For $k = 2$ and $c = 4$ (e.g., $High_capacity = OC-192$, $Low_capacity = OC-48$):



$c=4$, e.g., OC-192/OC-48
 $k=2$, e.g., 25 microsec/12.5 microsec

FIG. 9

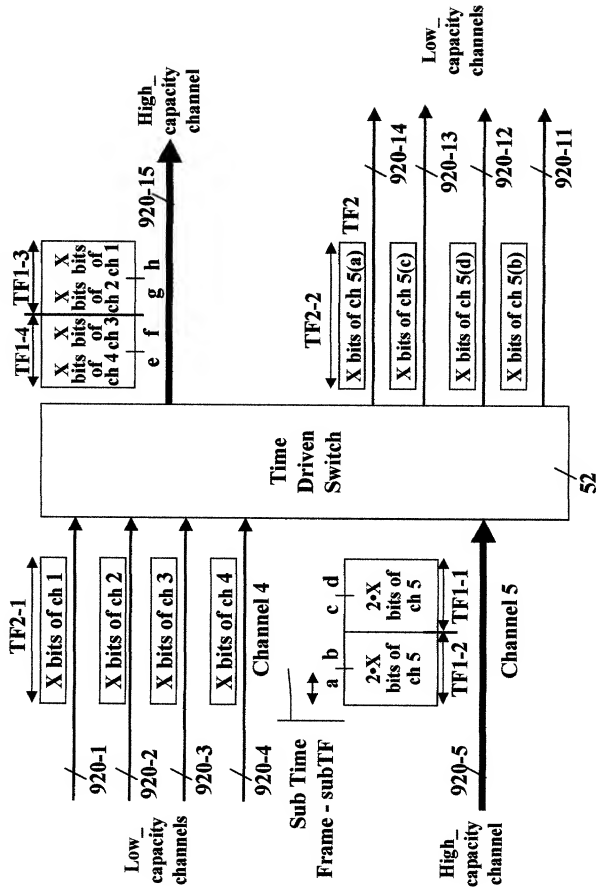


FIG. 10

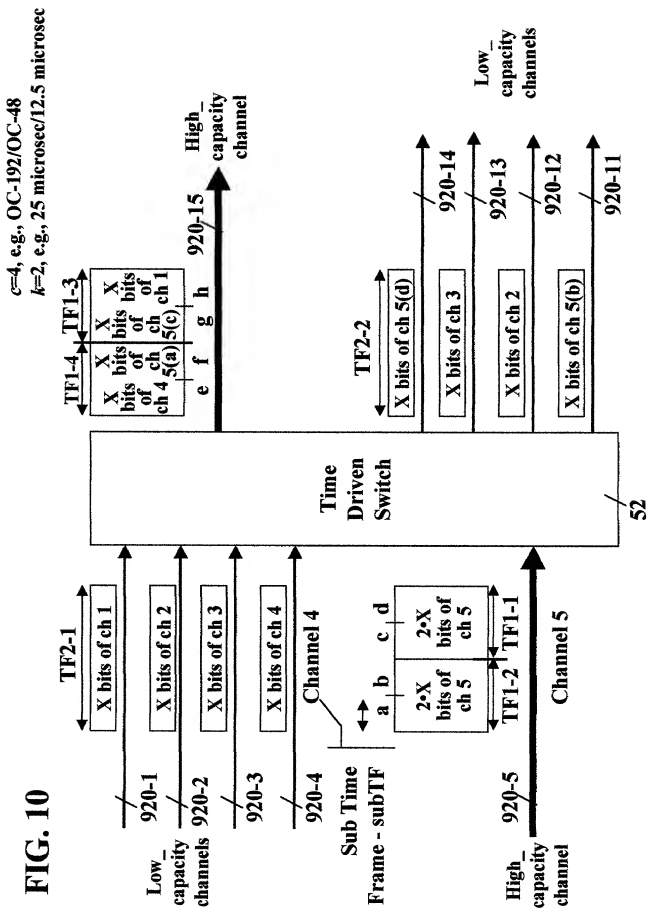


FIG. 11

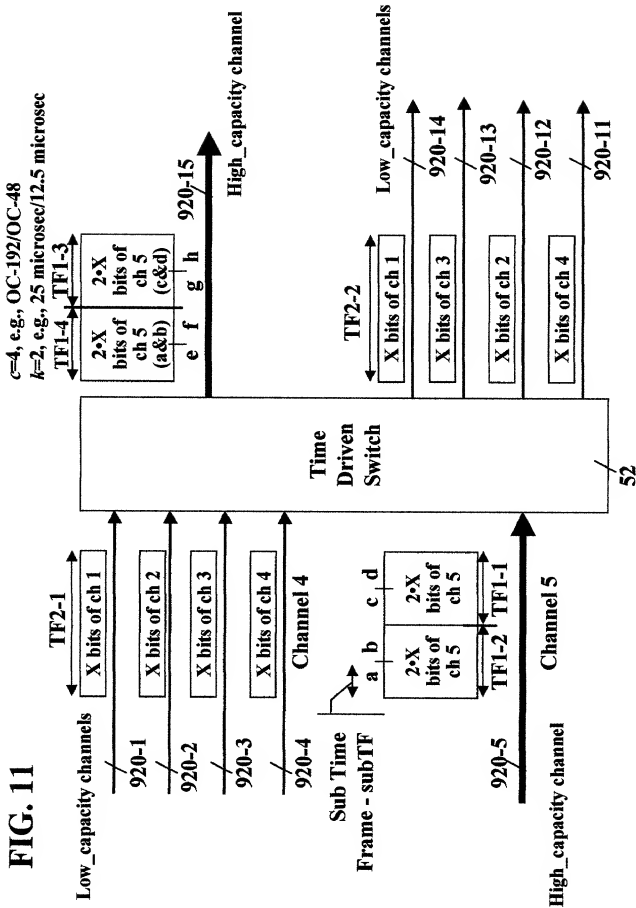


FIG. 12A

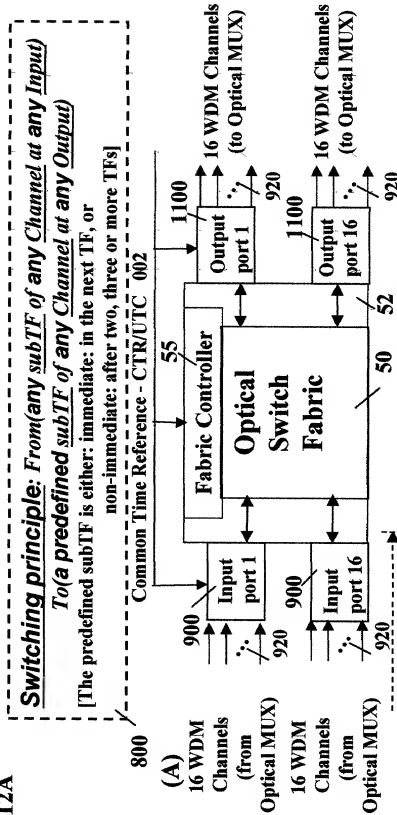


FIG. 12B

Phase 1

TF_{i,j}(t) - e.g., 62.5 μs
 Receiving & Alignment

FIG. 12C

Phase 1

TF_{i,j}(t) - e.g., 62.5 μs
 Receiving & Alignment

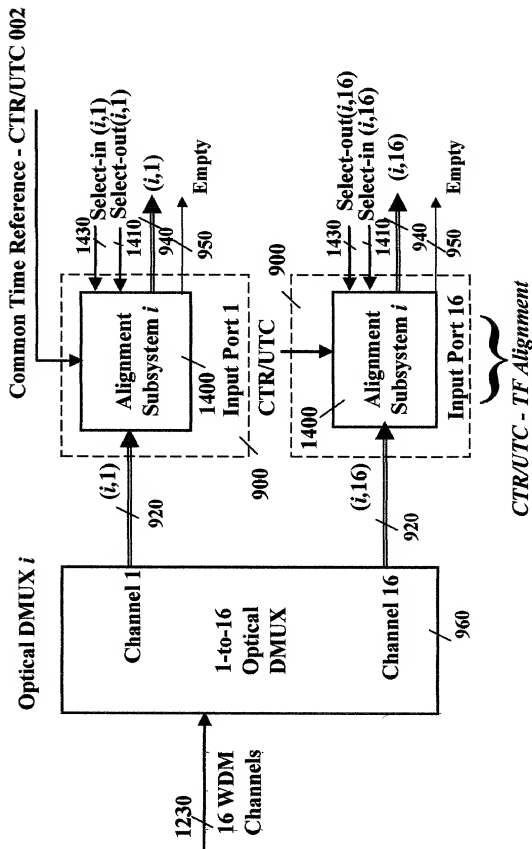
Phase 2

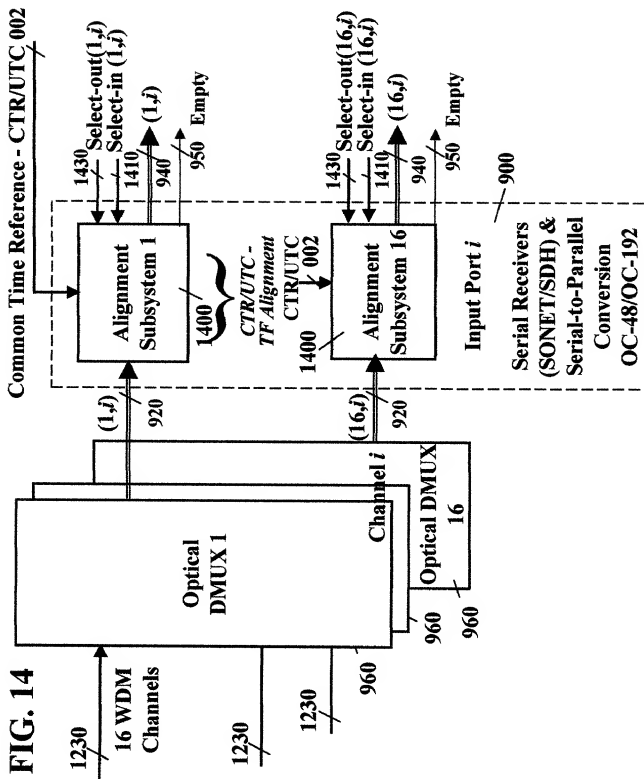
subTF(t+T) - 15.325 μs
 Switching

Phase 3

TF_{i,j}(t) - e.g., 62.5 μs
 Transmitting

FIG. 13





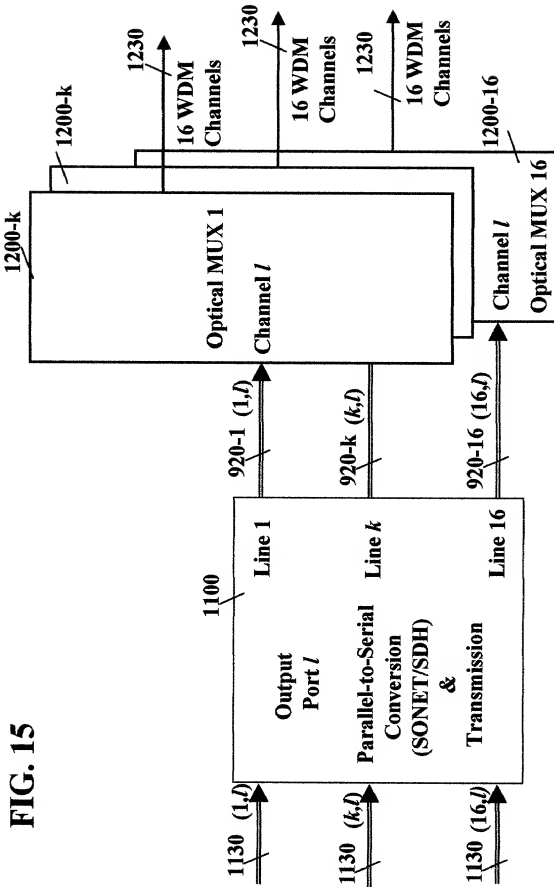


FIG. 15

FIG. 16

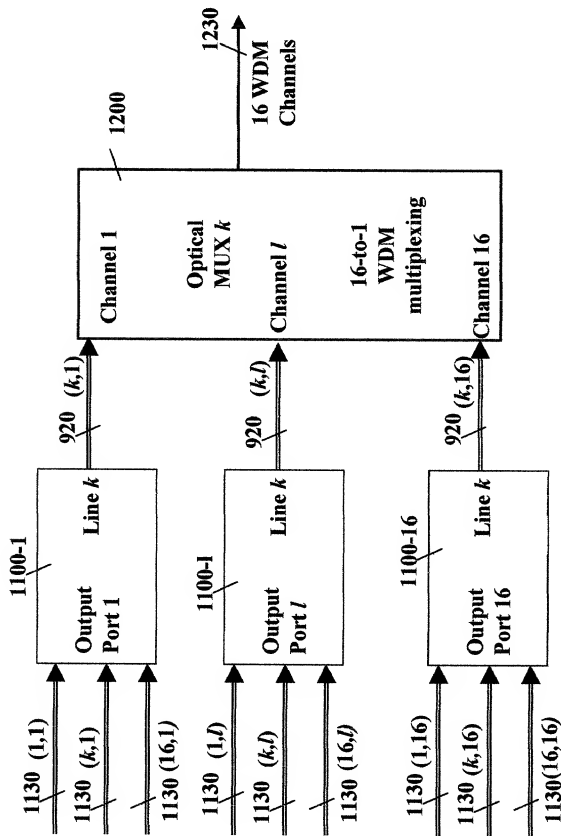


FIG. 17 N: number of input/output channels. E.g., N=256

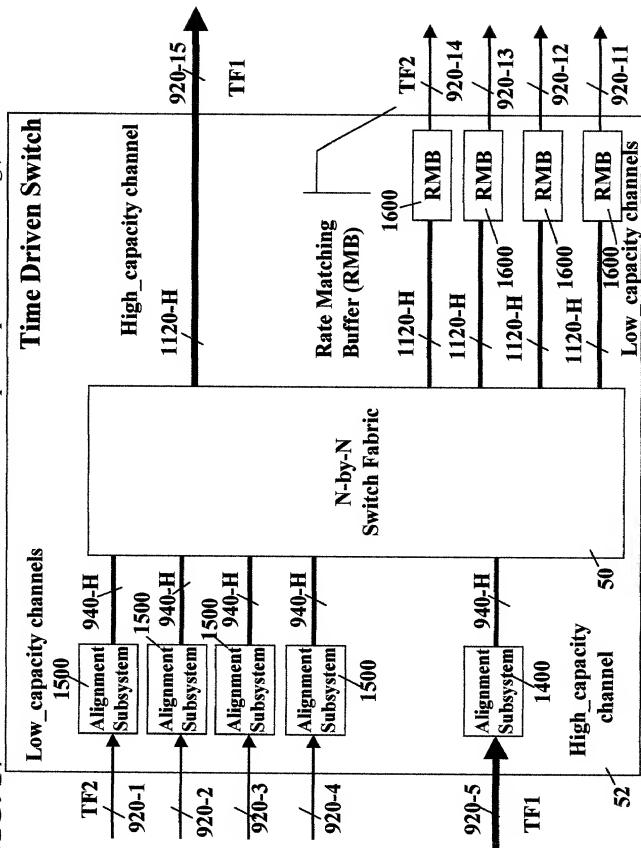
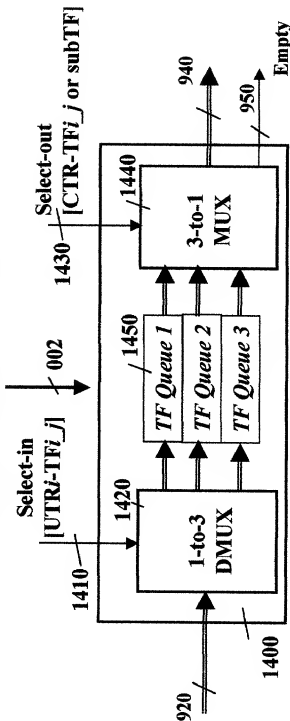


FIG. 18

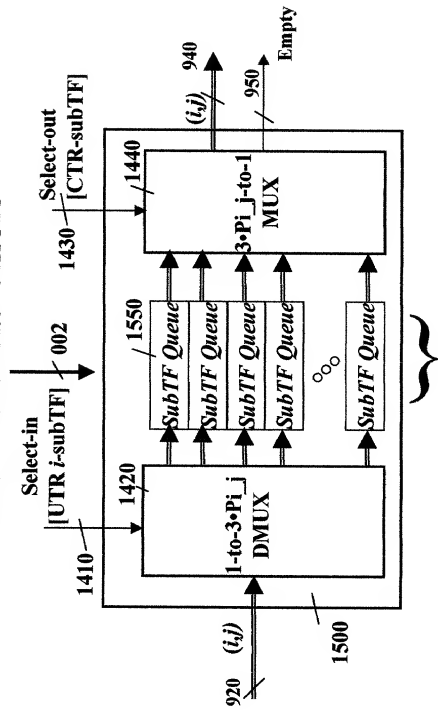
TF_{i,j}: Time frame duration on channel *j* at Input Interface *i*.
UTR_i: UTR on link connected to Input Interface *i*
 Common Time Reference - CTR/UTC



Alignment Subsystem for Channel *j* at Input Interface *i*
with a Plurality of Time Frame Queues

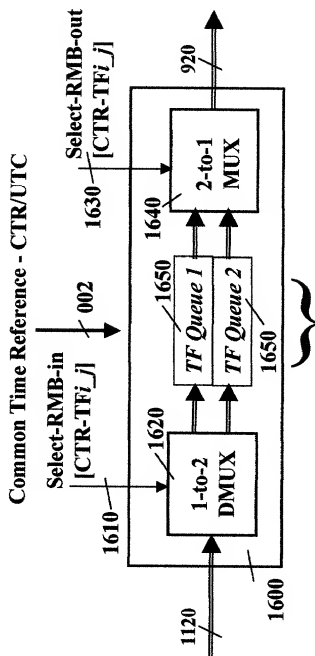
$TF_{i,j}$: Time frame duration on channel j at Input Interface i .
 UTR_i : UTR on link connected to Input Interface i
 $Pi_j = TF_{i,j}/subTF$

Common Time Reference - CTR/UTC

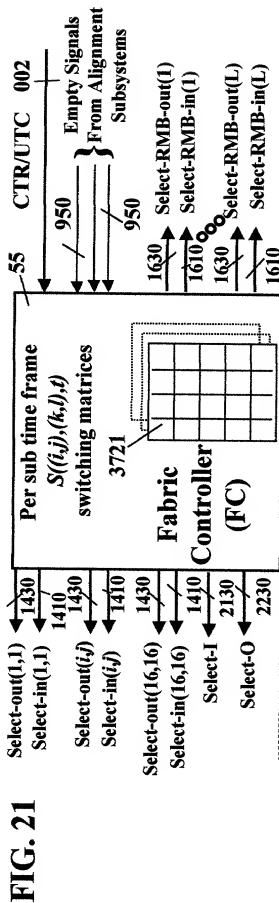


Alignment Subsystem for high capacity Channel j at Input Interface i
 with a Plurality of Sub-Time Frame Queues

FIG. 20 $TF_i j$: Time frame duration on channel j at Input Interface i .
 UTR i : UTR on link connected to Input Interface i



Rate Matching Buffer for Channel j at Output Interface i
with a Plurality of Time Frame Queues
 (Also single buffer with dual access memory with single phase switching and forwarding)



Fabric controller (FC):
 $S(i,j),(k,l),t$ - switching matrix for every sub-time frame in each time cycle and super cycle.

The matrix defines which input channel i,j should be connected to output channel k,l - in sub time frame t , where $S(i,j),(k,l),t=1$:

1. At every sub-time frame an input channel can be connected to one or more output optical channels (multicast - MCST)
2. At every sub-time frame an output optical channel can be connected to at most one input optical channel

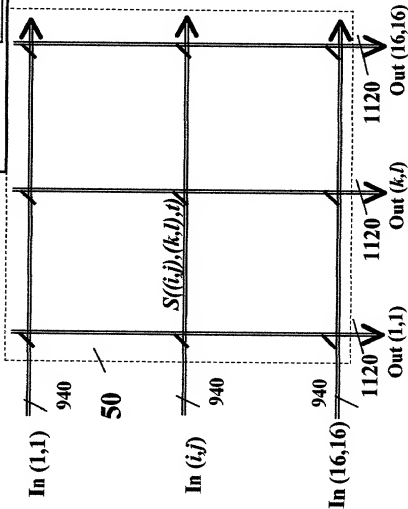
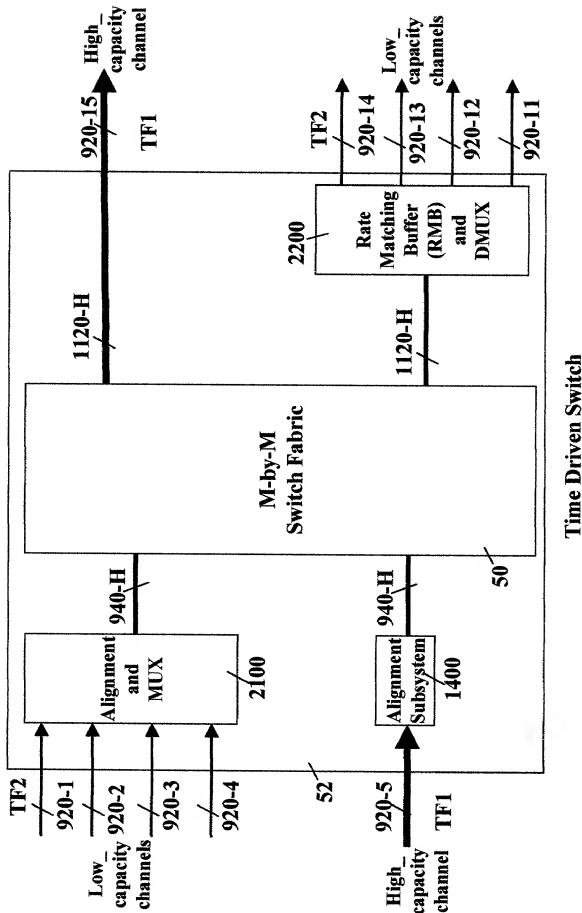


FIG. 22

N: number of input/output channels. E.g., $N=256$
 $M \cdot \text{High_capacity} = N_{\text{high}} \cdot \text{High_capacity} + N_{\text{low}} \cdot \text{Low_capacity}$
 $M < N$



The diagram illustrates a multi-rate switch architecture. A central dashed box contains a 'c-by-1 selector' block with 'c = 4' outputs. This selector is connected to four 'Low_capacity channels' (920-1 to 920-4) and a 'High_capacity' output (940-H). Each low-capacity channel consists of an 'Alignment Subsystem' and a 'TF! j' input. The selector also receives 'Select-in(i,j) [UTRk-TF! j]' and 'Select-out(i,j) [CTR - subTF]' signals. The output of the selector is connected to a 'To the Switch Fabric' block.

To the Switch Fabric

FIG. 24

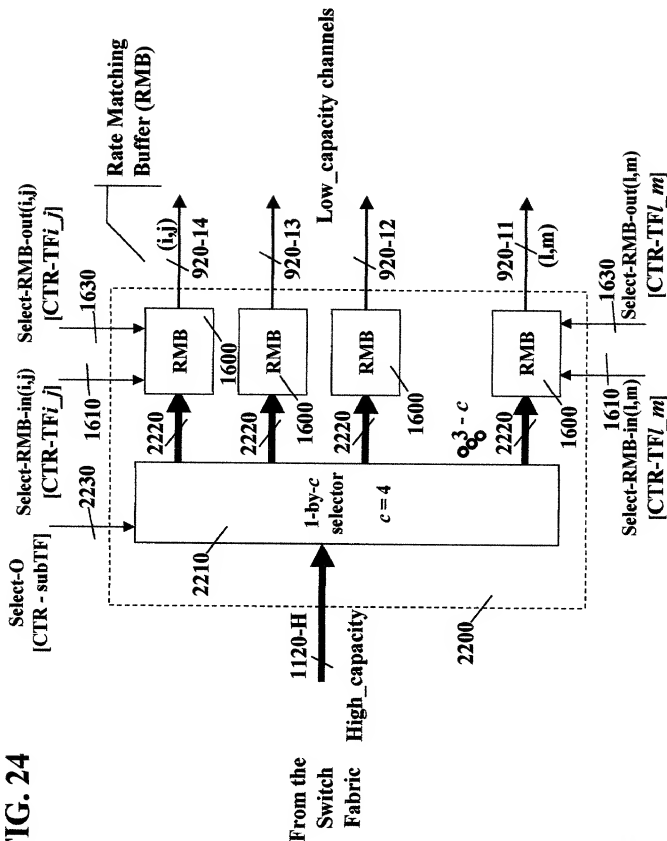


FIG. 25

N: number of input/output channels. E.g., $N=256$
 $L \cdot \text{Low_capacity} = N_{\text{high}} \cdot \text{High_capacity} + N_{\text{low}} \cdot \text{Low_capacity}$
 $L > N$

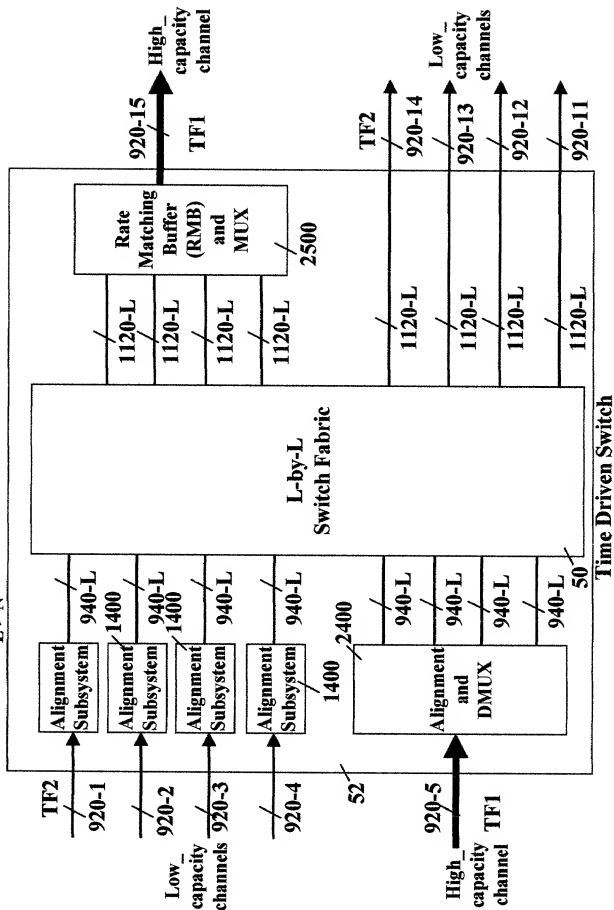


FIG. 26

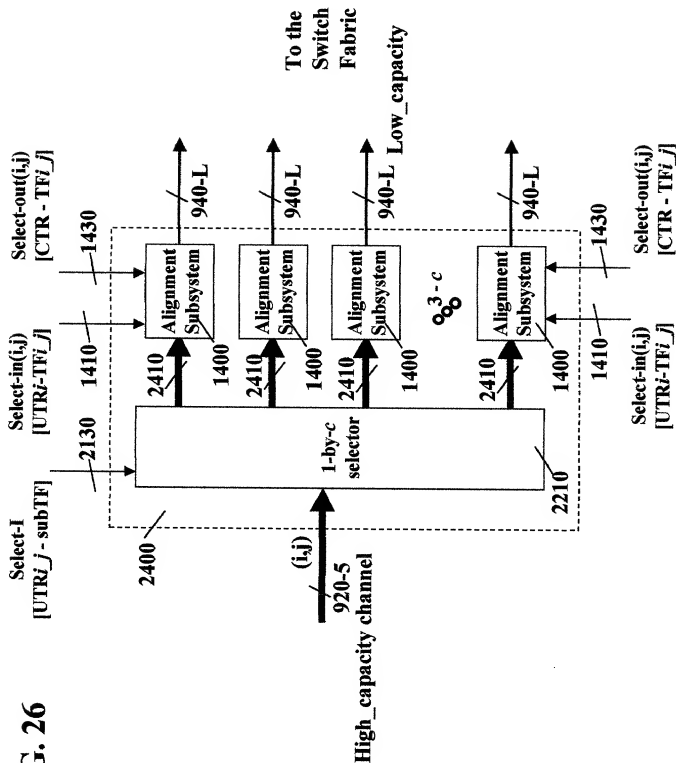


FIG. 27

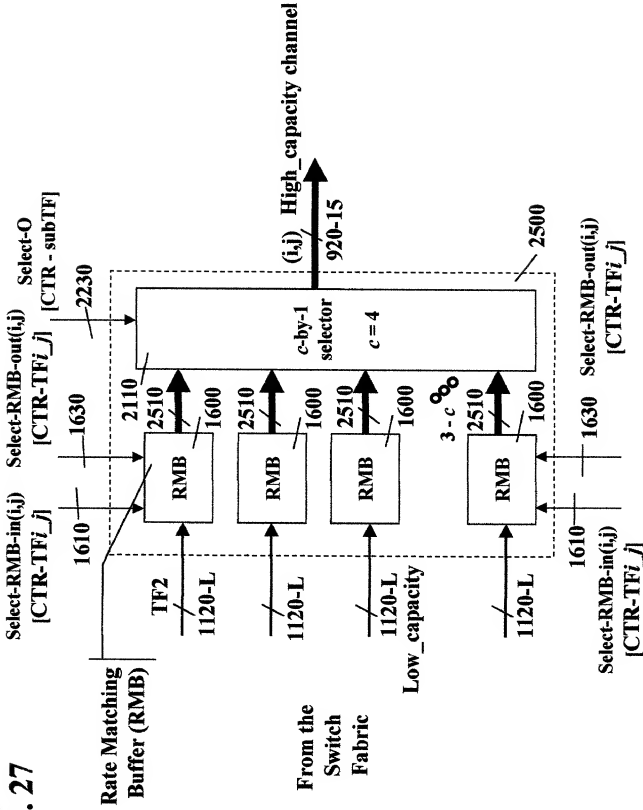


FIG. 28

N: number of input/output channels. E.g., N=256
 $L \cdot \text{Low_capacity} = N \cdot \text{High_capacity}$
 $L = c \cdot N > N$

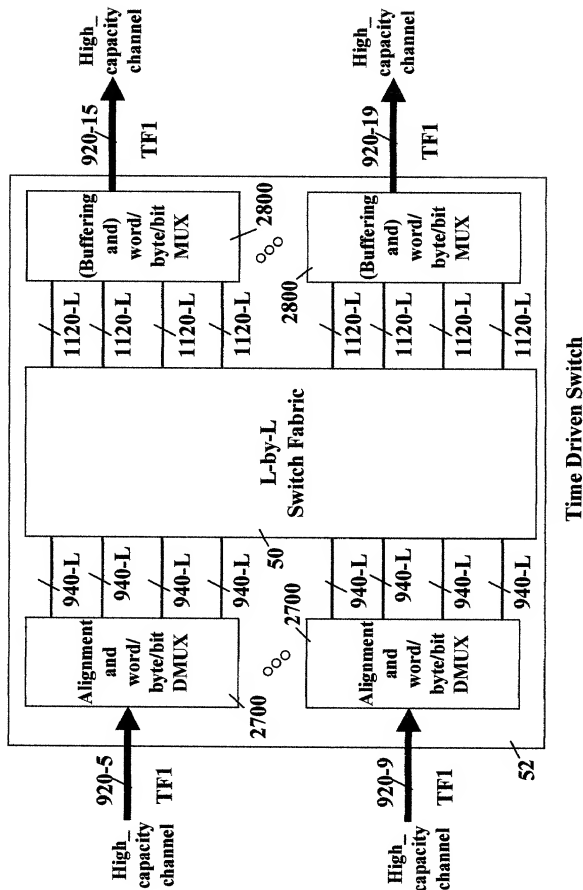
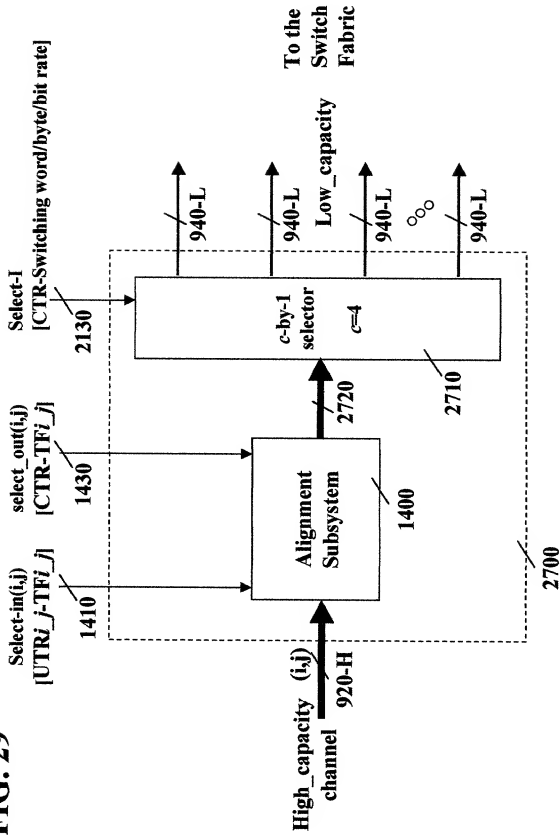


FIG. 29



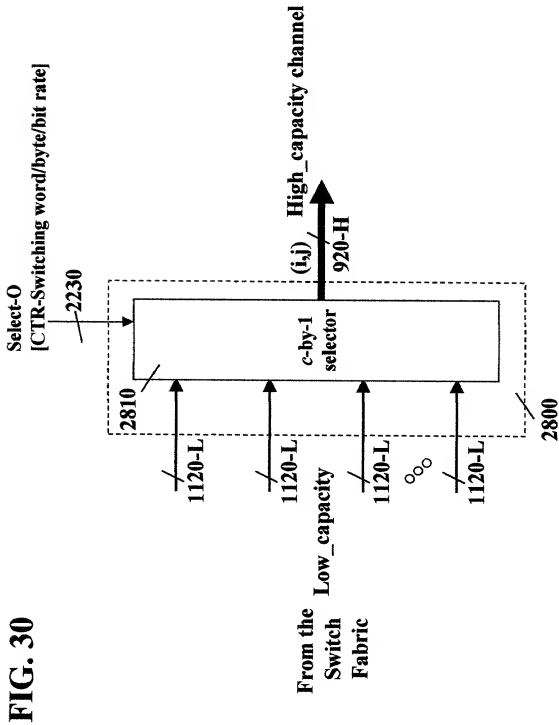


FIG. 31

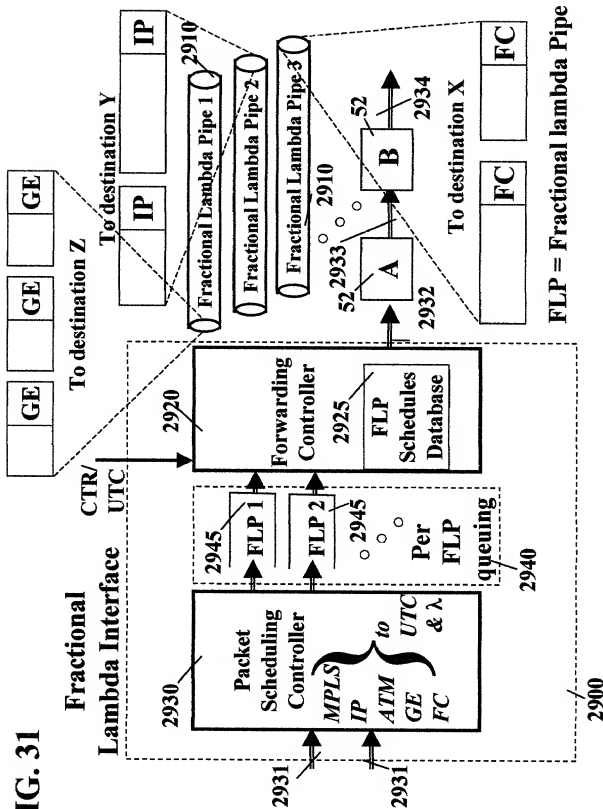


FIG. 32

Channel Capacity		TF Duration	TF Size	STS-1s	TFs/s
51.84	STS- 1	250	1620	1512	2
		500	3240	3024	4
		1000	6480	6048	8
155.52	STS- 3	125	2430	2268	3
		250	4860	4536	6
		500	9720	9072	12
622.08	STS- 12	62.5	4860	4536	6
		125	9720	9072	12
		250	19440	18144	24
2488.32	STS- 48	62.5	19440	18144	24
		31.25	9720	9072	12
		15.625	4860	4536	6
9953.28	STS- 192	7.8125	9720	9072	12
		15.625	19440	18144	24
		125	15625	15625	19.3
1000	GE	100	12500	12500	15.4
		80	10000	10000	12.3
10000	10GE	15.625	19531.25	19531.3	24.1
		12.5	15625	15625	19.3
		10	12500	12500	15.4

FIG. 33

Ch Capacity		TF Dur.	TF Size	GE TFs	TFs/s
1000	GE	80	10000	1.0	12500
51.84	STS- 1	250	1512	0.15	4000
		500	3024	0.30	2000
		1000	6048	0.60	1000
155.5	STS- 3	125	2268	0.23	8000
		250	4536	0.45	4000
		500	9072	0.91	2000
622.1	STS- 12	62.5	4536	0.45	16000
		125	9072	0.91	8000
		250	18144	1.81	4000
2488	STS- 48	62.5	18144	1.81	16000
		31.25	9072	0.91	32000
		15.625	4536	0.45	64000
9953	STS- 192	7.8125	9072	0.91	128000
		15.625	18144	1.81	64000
10000	10GE	8	10000	1.00	125000
		16	20000	2.00	62500

FIG. 34

Ch Capacity		TF Dur.	TF Size	GE TFs	TFs/s
1000	GE	62.5	7812.5	1.0	16000
51.84	STS- 1	250	1512	0.19	4000
		500	3024	0.39	2000
		1000	6048	0.77	1000
155.52	STS- 3	125	2268	0.29	8000
		250	4536	0.58	4000
		500	9072	1.16	2000
622.08	STS- 12	62.5	4536	0.58	16000
		125	9072	1.16	8000
		250	18144	2.32	4000
2488.32	STS- 48	62.5	18144	2.32	16000
		31.25	9072	1.16	32000
		15.625	4536	0.58	64000
9953.28	STS- 192	7.8125	9072	1.16	128000
		15.625	18144	2.32	64000
		12.5	15625	2.00	80000
10000	10GE	25	31250	4.00	40000

FIG. 35

TF Alignment of UTR(i) to UTC - with three input queues - principle of operation:

The same queue is not used simultaneously for:

1. Receiving data packets from the serial link, and
2. Forwarding data packets to the switch

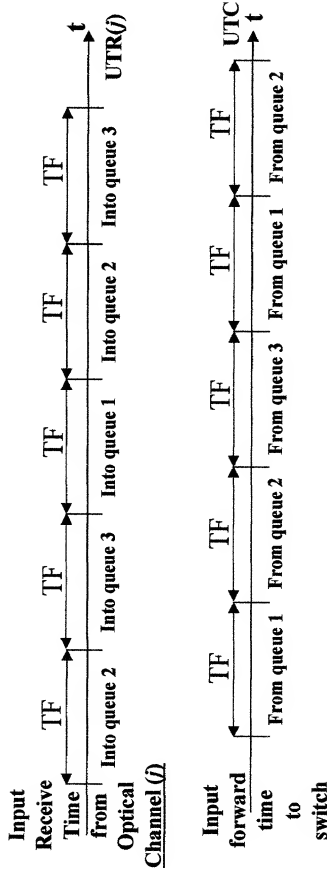


FIG. 36

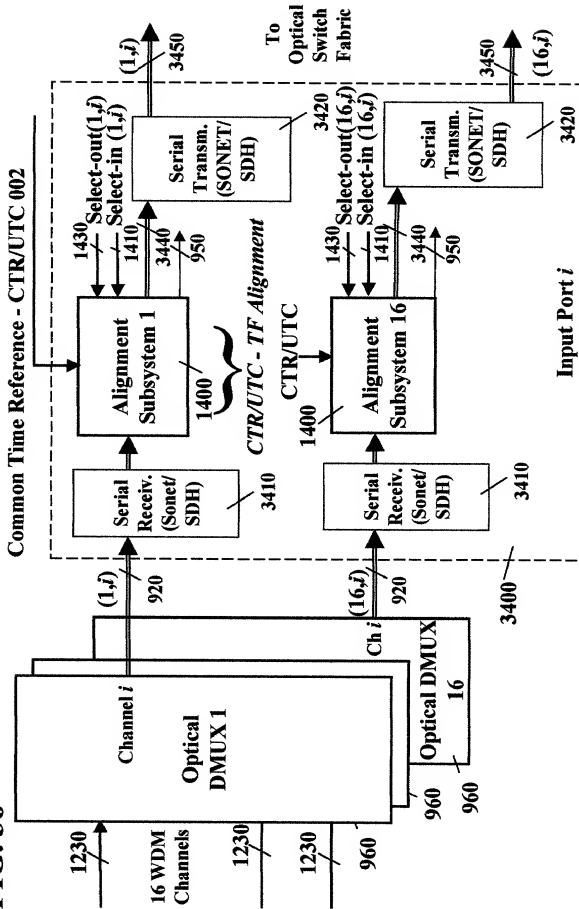
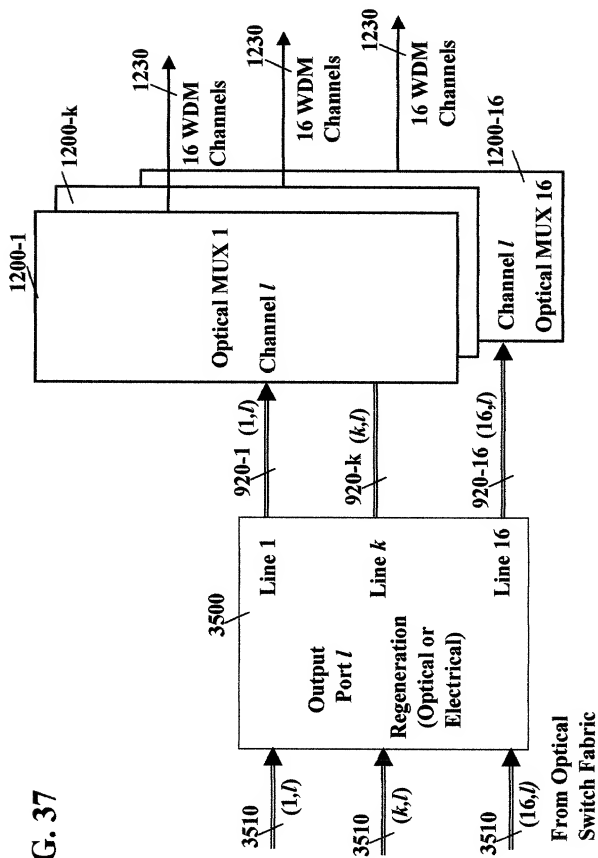


FIG. 37



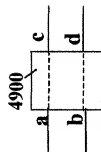


FIG. 38A

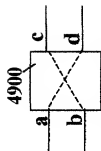


FIG. 38B

Straight Connection of a
 2-by-2 Optical Switching Block

Cross Connection of a
 2-by-2 Optical Switching Block

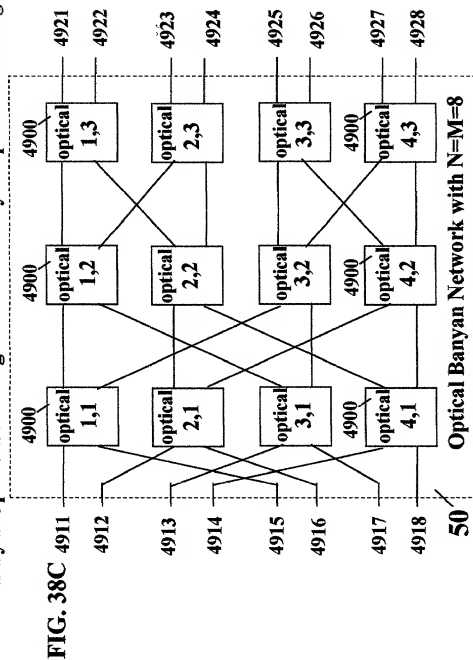
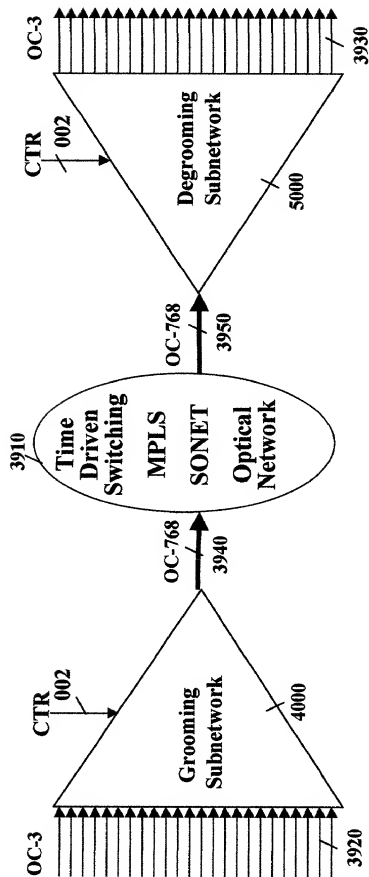


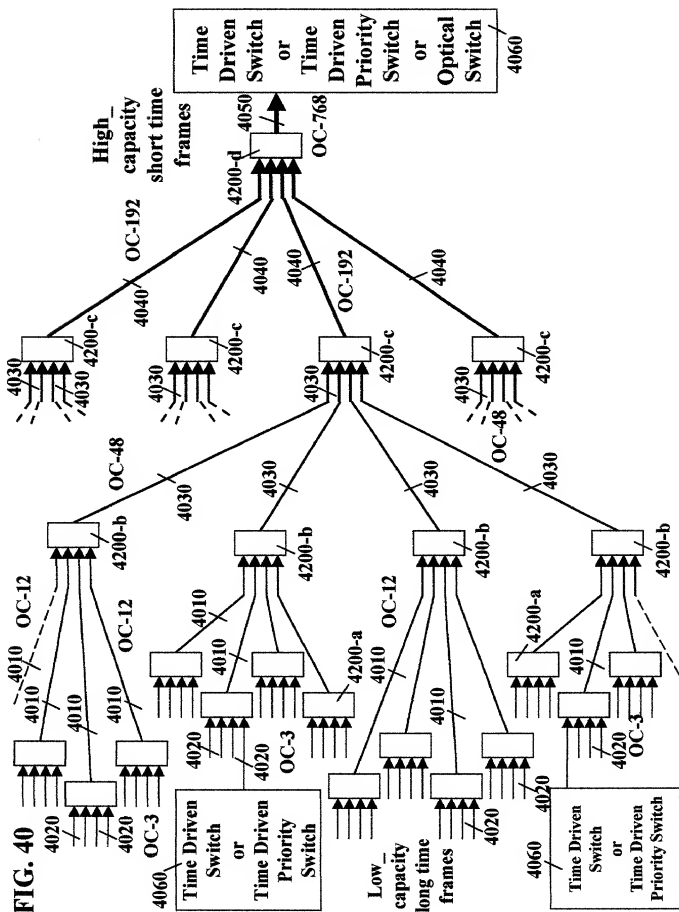
FIG. 38C

Optical Banyan Network with $N=M=8$

50

FIG. 39





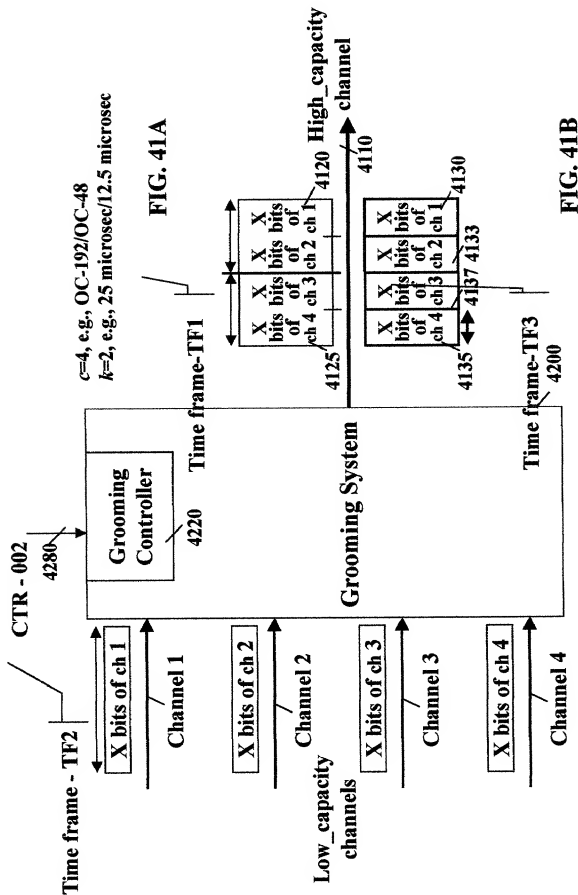


FIG. 42

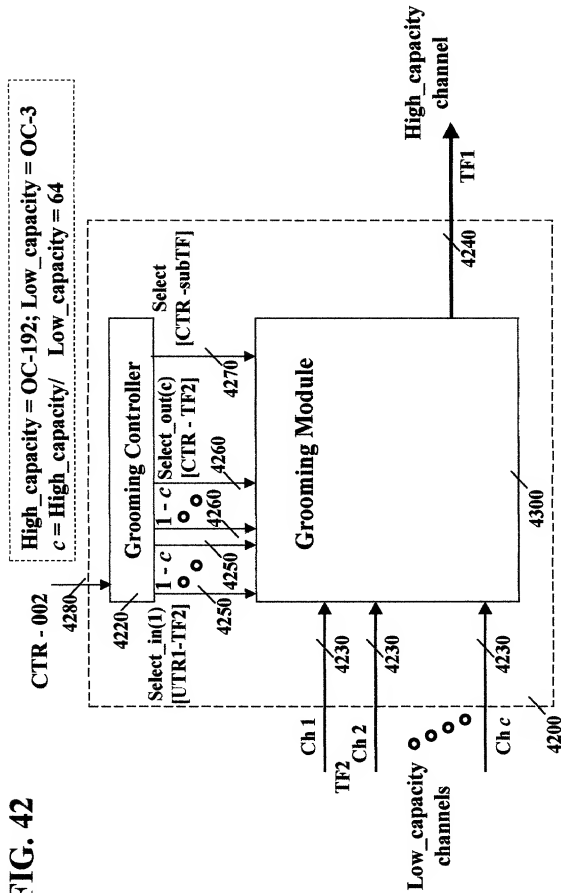


FIG. 43

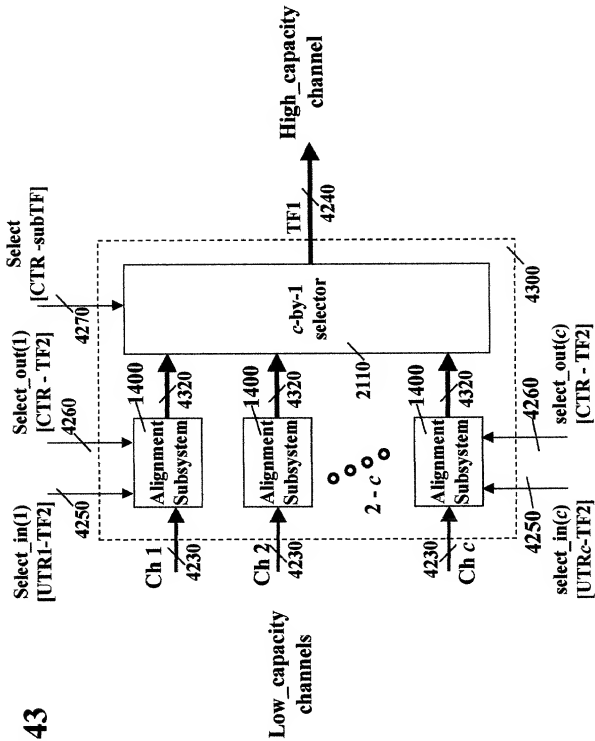
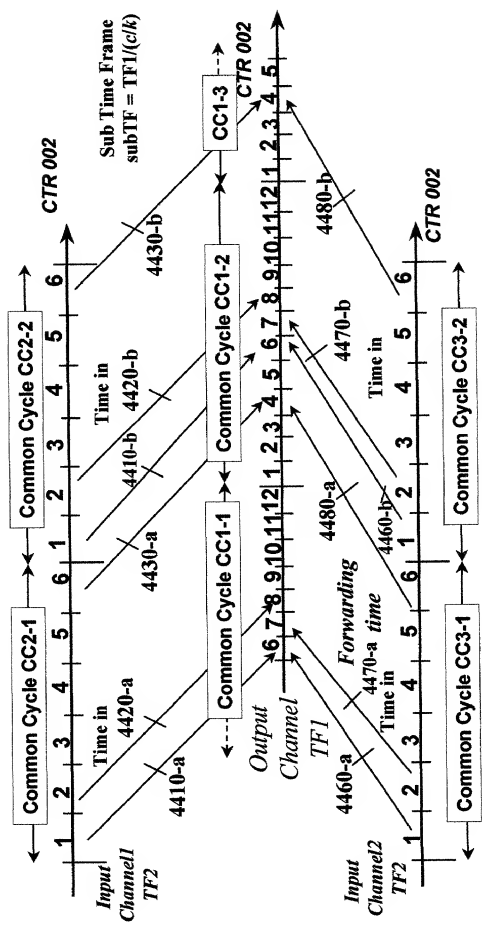


FIG. 44

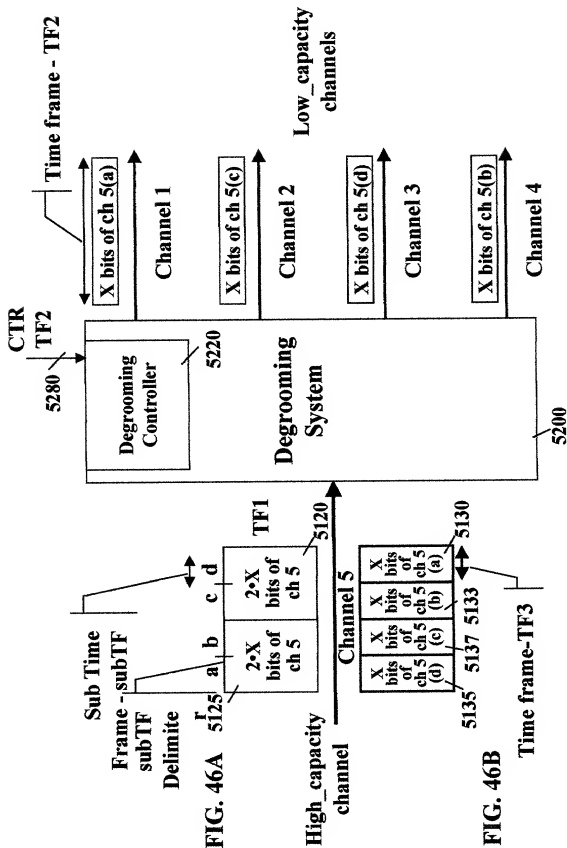
- $CC1_length \cdot TF1 = CC2_length \cdot TF2 = CC3_length \cdot TF2$
- $TF2 = (SC1_length / SC2_length) \cdot TF1 = k \cdot TF1$, where the common cycles of $TF1$ and $TF2$ are aligned with respect to UTC.

For $k = 2$ and $c = 4$ (e.g., High_capacity=OC-192, Low_capacity=OC-48):

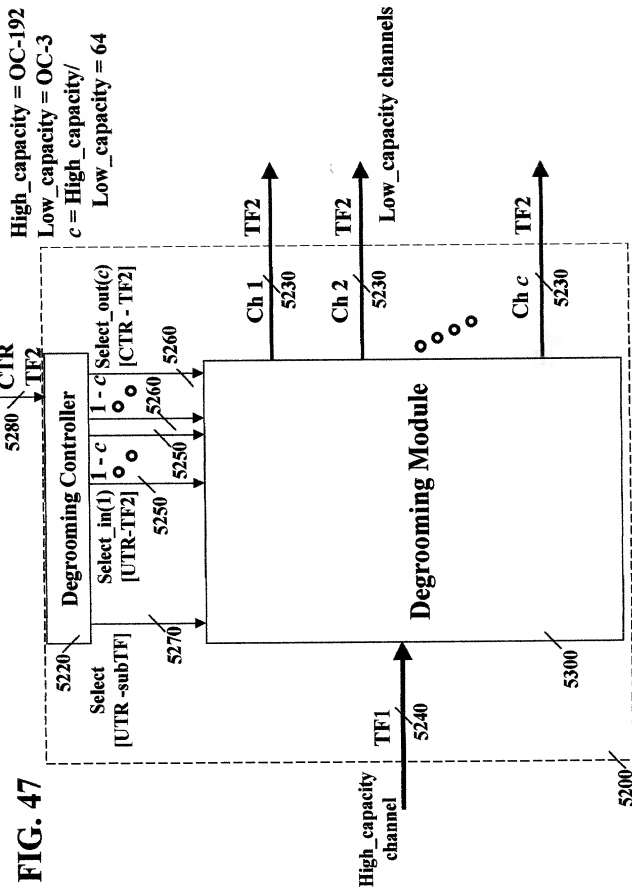


[illegible]

4060



c=4, e.g., OC-192/OC-48
 k=2, e.g., 25 microsec/12.5 microsec



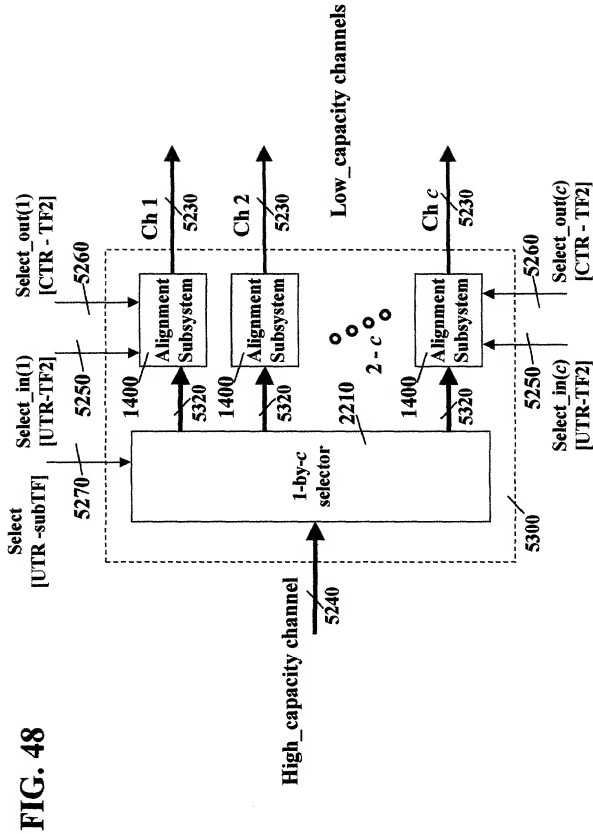
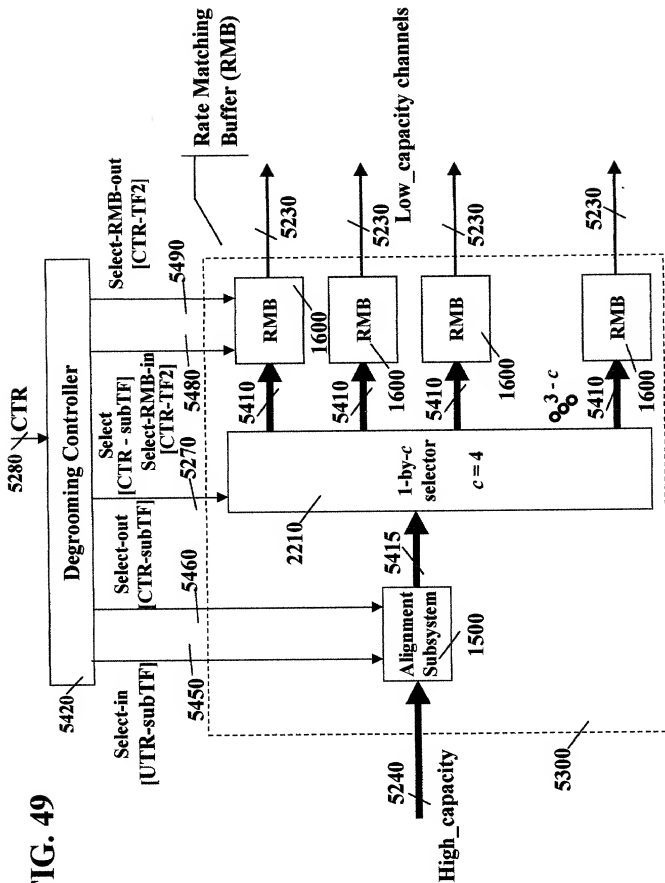


FIG. 49



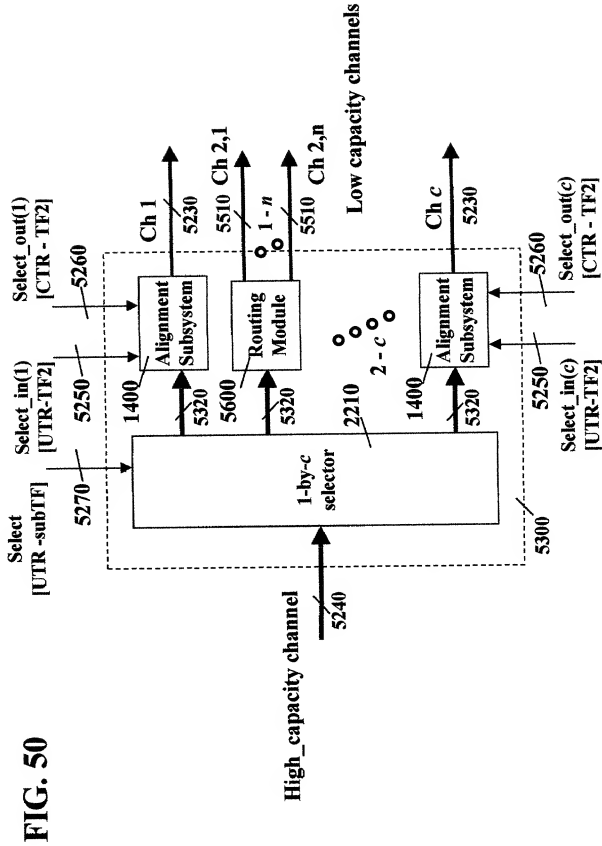


FIG. 51

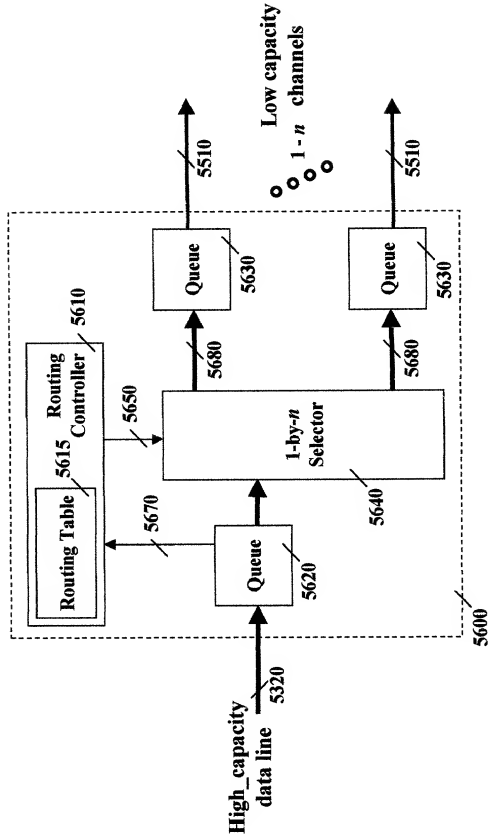


FIG. 52

- $CC1_length \cdot TF1 = CC2_length \cdot TF2 = CC3_length \cdot TF2$
 - $TF2 = (SC1_length / SC2_length) \cdot TF1 = k \cdot TF1$, where the common cycles of $TF1$ and $TF2$ are aligned with respect to UTC.
- For $k = 2$ and $c = 4$ (e.g., High_capacity=OC-192, Low_capacity=OC-48):

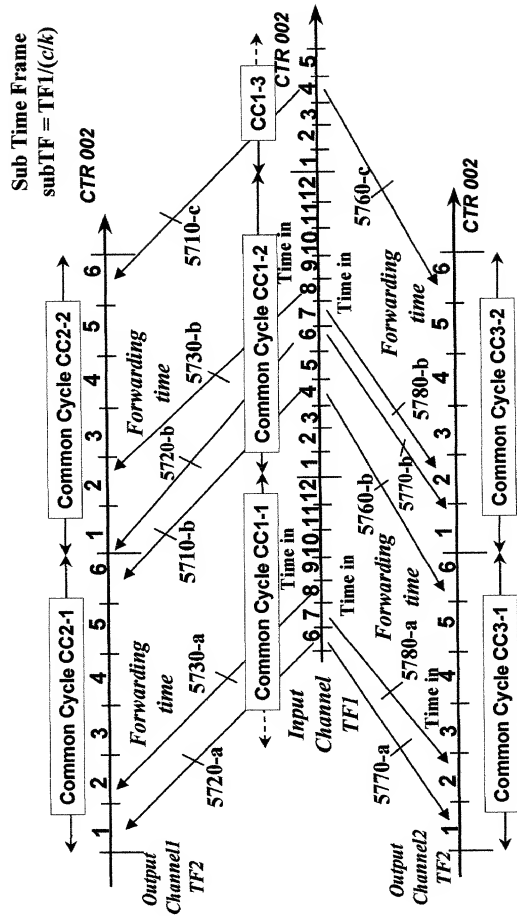


FIG. 53

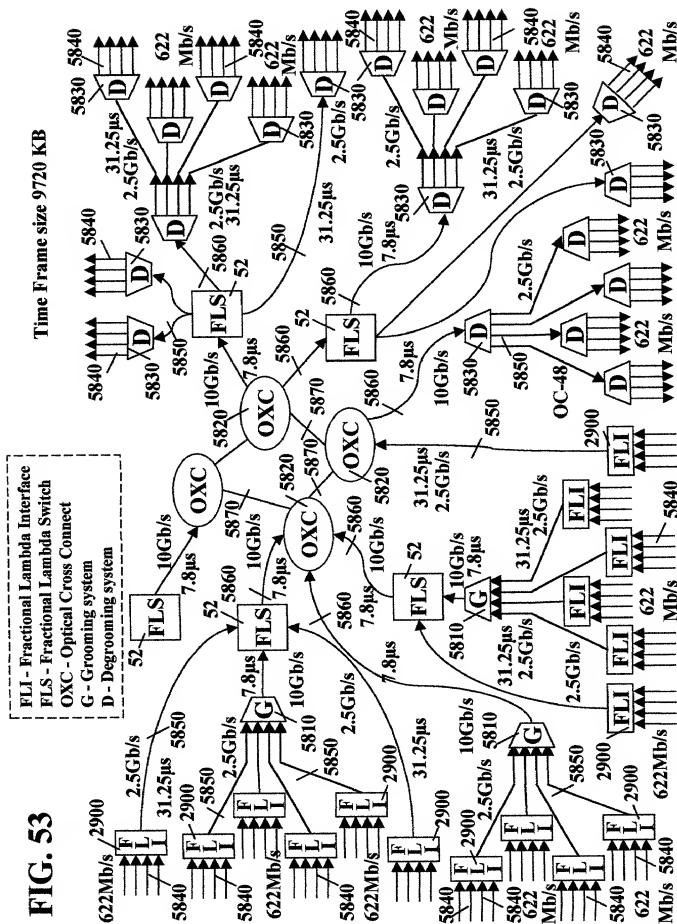
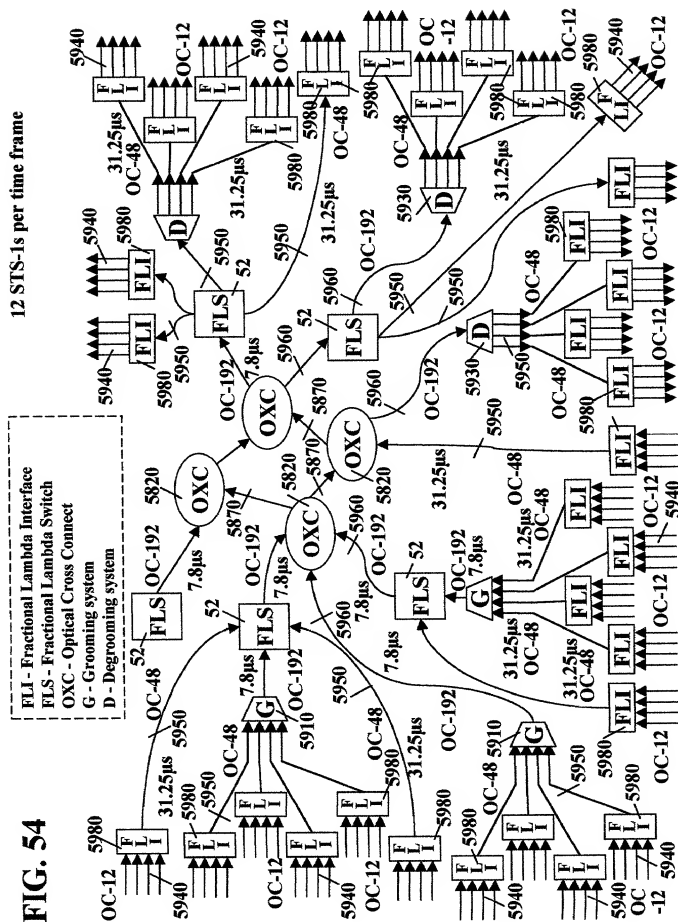
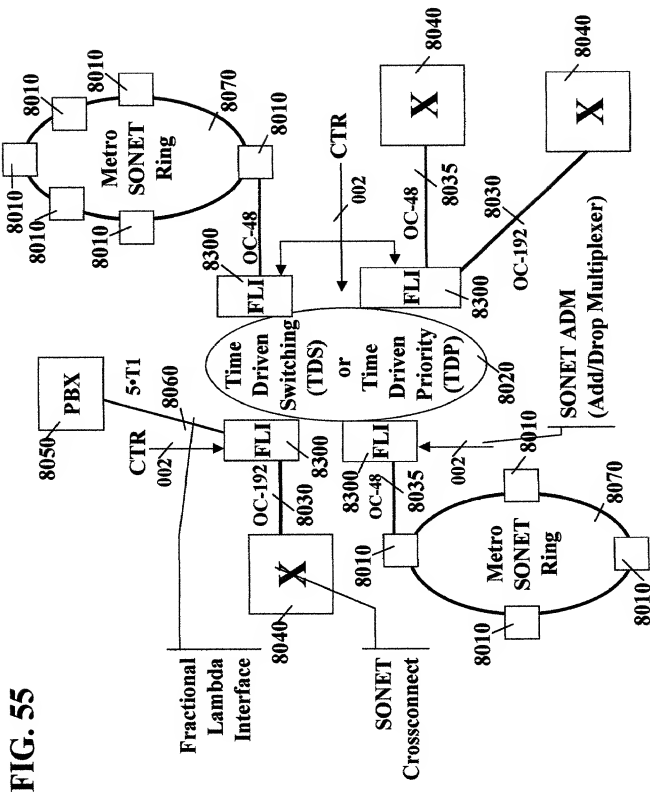
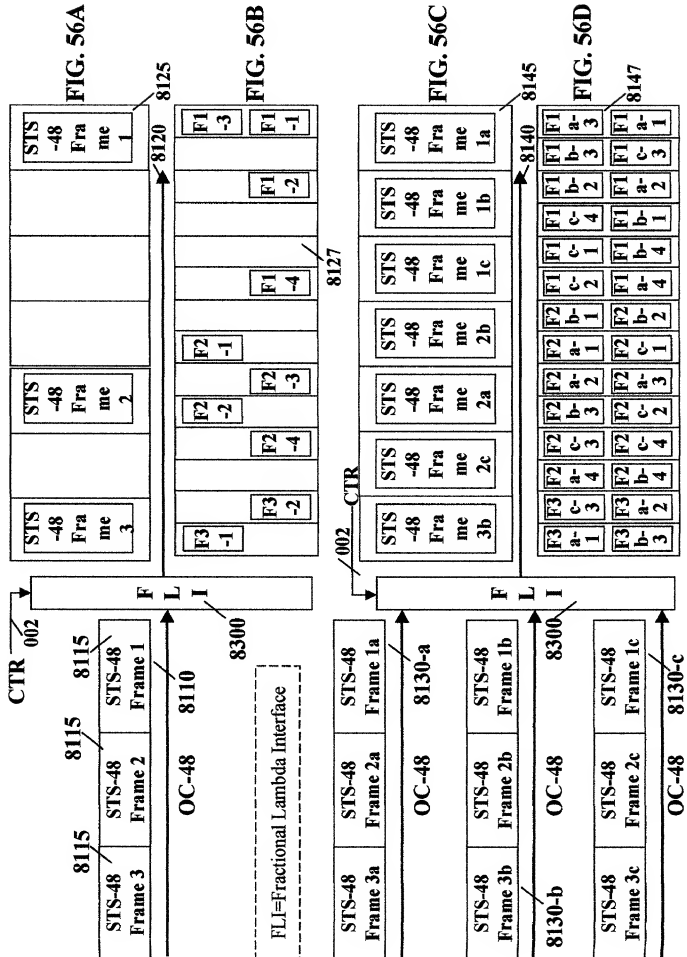
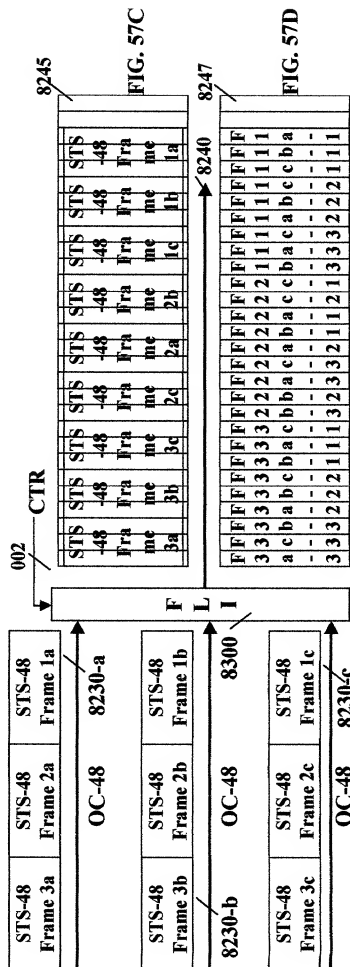
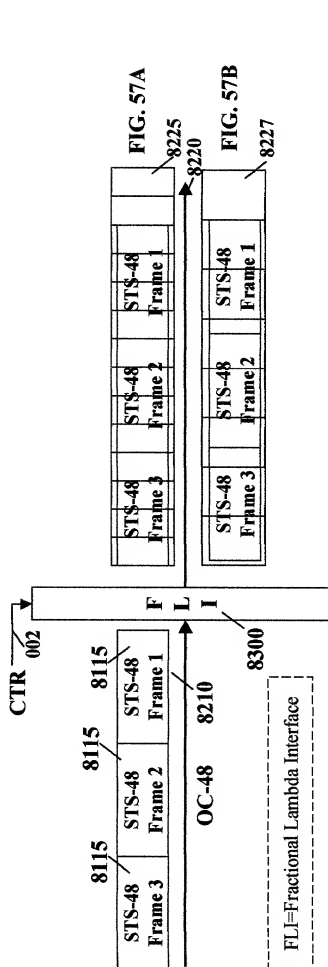


FIG. 54









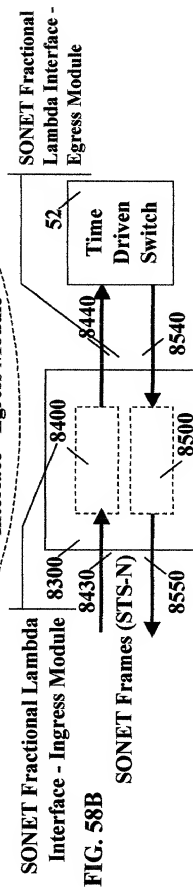
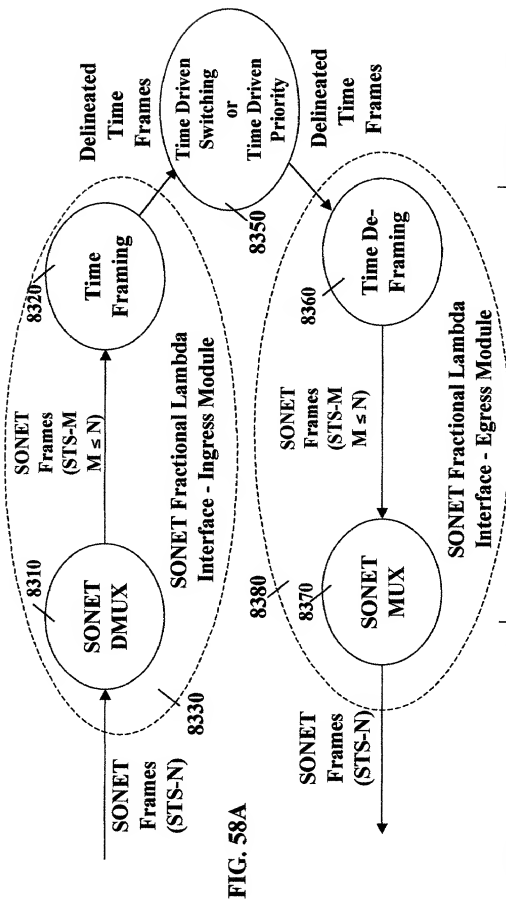


FIG. 59

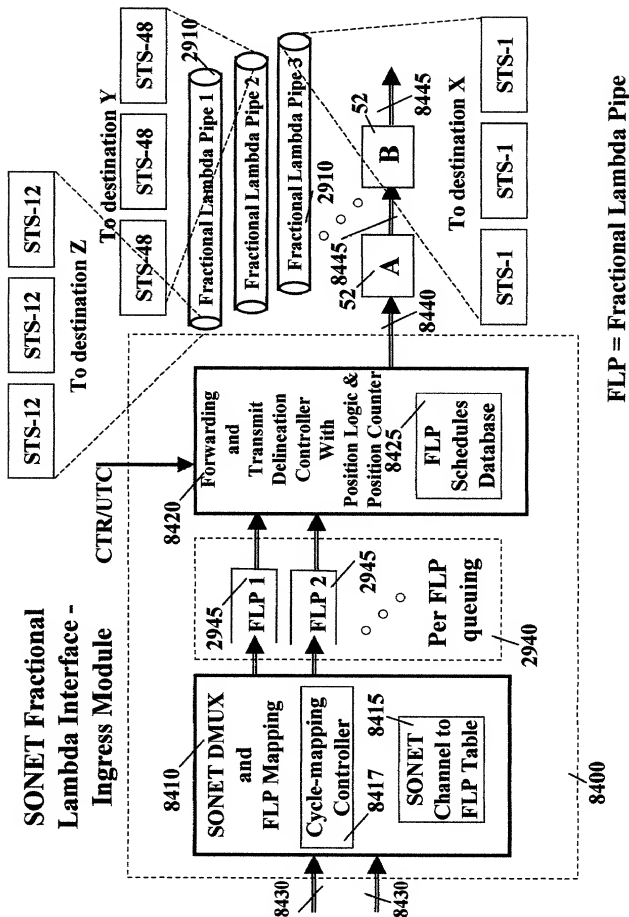
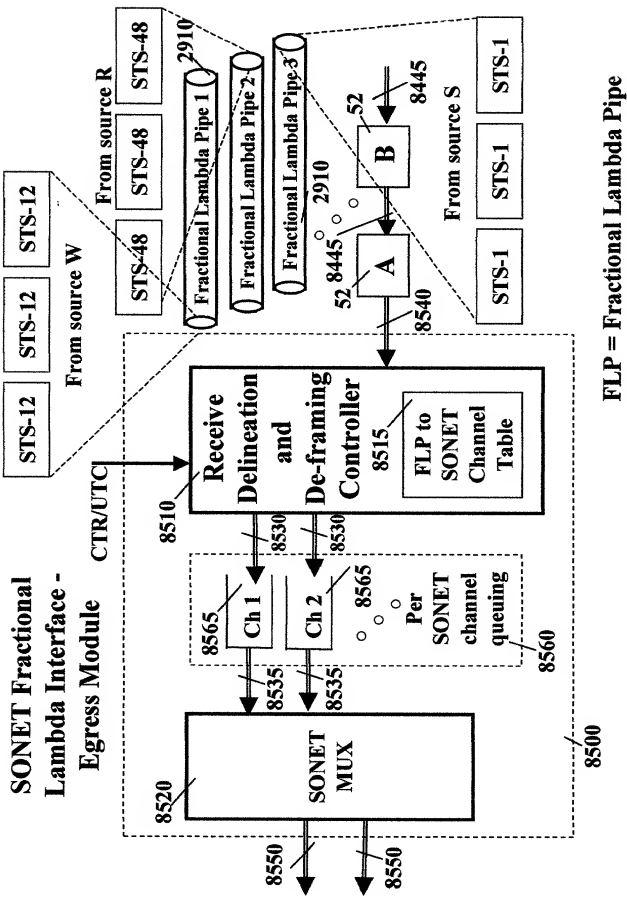


FIG. 60



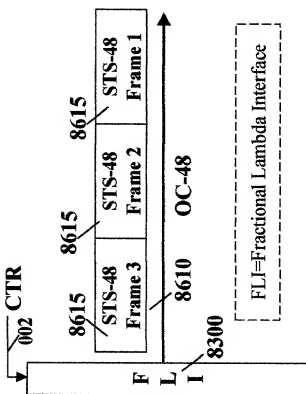


FIG. 61A

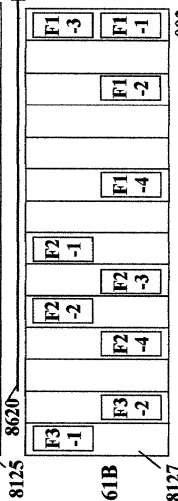


FIG. 61B

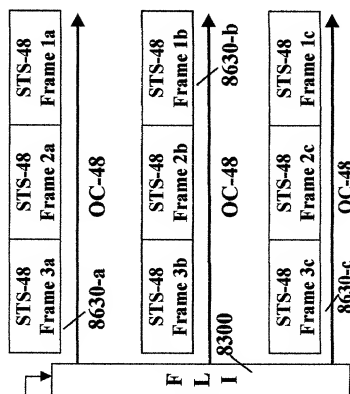


FIG. 61C

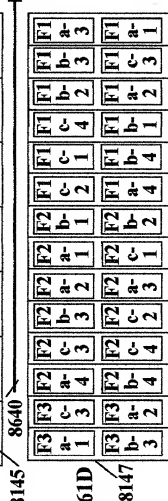
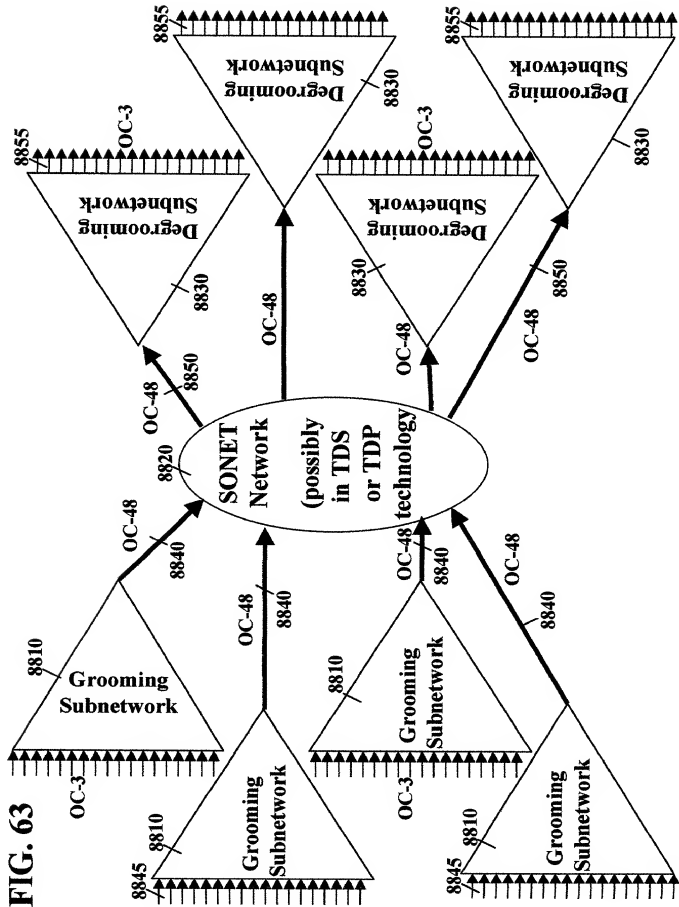
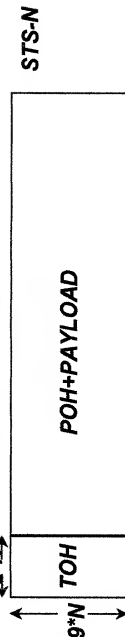
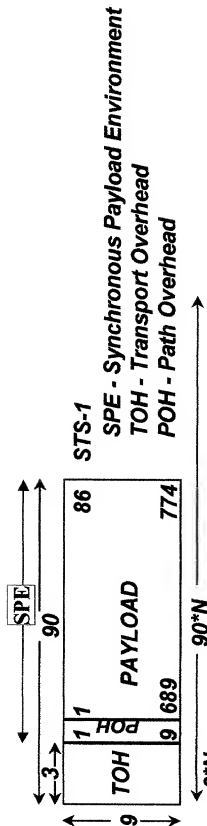


FIG. 61D





- SONET - synchronous optical network
- Multiplexing method: byte interleaving
- Signal hierarchy: OC-N (STS-N)
 - STS-N rate: $N \times 51.84$ Mb/s
 - Frame format: 9 rows by $90 \times N$ columns
 - capacity: $N \times 810$ bytes in 125 microseconds.
 - overhead: $N \times 27$ bytes
 - payload: $N \times 783$ bytes



The diagram illustrates a switch architecture (52) and its timing. The switch architecture includes a Switch Controller (002) and a Switch Fabric (50). The Switch Controller is connected to multiple Alignment Subsystems (6520, 6525) via bidirectional links (6513, 6515). Each Alignment Subsystem is connected to the Switch Fabric via bidirectional links (6520, 6525). The Alignment Subsystems are also connected to Input (6530) and Output (6535) ports. The Input and Output ports are connected to a series of data units (6540a, 6540b, 6540c, 6540d, 6540e, 6540f, 6540g, 6540h, 6540i, 6540j, 6540k, 6540l, 6540m, 6540n, 6540o, 6540p, 6540q, 6540r, 6540s, 6540t, 6540u, 6540v, 6540w, 6540x, 6540y, 6540z, 6540aa, 6540ab, 6540ac, 6540ad, 6540ae, 6540af, 6540ag, 6540ah, 6540ai, 6540aj, 6540ak, 6540al, 6540am, 6540an, 6540ao, 6540ap, 6540aq, 6540ar, 6540as, 6540at, 6540au, 6540av, 6540aw, 6540ax, 6540ay, 6540az, 6540ba, 6540bb, 6540bc, 6540bd, 6540be, 6540bf, 6540bg, 6540bh, 6540bi, 6540bj, 6540bk, 6540bl, 6540bm, 6540bn, 6540bo, 6540bp, 6540bq, 6540br, 6540bs, 6540bt, 6540bu, 6540bv, 6540bw, 6540bx, 6540by, 6540bz, 6540ca, 6540cb, 6540cc, 6540cd, 6540ce, 6540cf, 6540cg, 6540ch, 6540ci, 6540cj, 6540ck, 6540cl, 6540cm, 6540cn, 6540co, 6540cp, 6540cq, 6540cr, 6540cs, 6540ct, 6540cu, 6540cv, 6540cw, 6540cx, 6540cy, 6540cz, 6540da, 6540db, 6540dc, 6540dd, 6540de, 6540df, 6540dg, 6540dh, 6540di, 6540dj, 6540dk, 6540dl, 6540dm, 6540dn, 6540do, 6540dp, 6540dq, 6540dr, 6540ds, 6540dt, 6540du, 6540dv, 6540dw, 6540dx, 6540dy, 6540dz, 6540ea, 6540eb, 6540ec, 6540ed, 6540ee, 6540ef, 6540eg, 6540eh, 6540ei, 6540ej, 6540ek, 6540el, 6540em, 6540en, 6540eo, 6540ep, 6540eq, 6540er, 6540es, 6540et, 6540eu, 6540ev, 6540ew, 6540ex, 6540ey, 6540ez, 6540fa, 6540fb, 6540fc, 6540fd, 6540fe, 6540ff, 6540fg, 6540fh, 6540fi, 6540fj, 6540fk, 6540fl, 6540fm, 6540fn, 6540fo, 6540fp, 6540fq, 6540fr, 6540fs, 6540ft, 6540fu, 6540fv, 6540fw, 6540fx, 6540fy, 6540fz, 6540ga, 6540gb, 6540gc, 6540gd, 6540ge, 6540gf, 6540gg, 6540gh, 6540gi, 6540gj, 6540gk, 6540gl, 6540gm, 6540gn, 6540go, 6540gp, 6540gq, 6540gr, 6540gs, 6540gt, 6540gu, 6540gv, 6540gw, 6540gx, 6540gy, 6540gz, 6540ha, 6540hb, 6540hc, 6540hd, 6540he, 6540hf, 6540hg, 6540hh, 6540hi, 6540hj, 6540hk, 6540hl, 6540hm, 6540hn, 6540ho, 6540hp, 6540hq, 6540hr, 6540hs, 6540ht, 6540hu, 6540hv, 6540hw, 6540hx, 6540hy, 6540hz, 6540ia, 6540ib, 6540ic, 6540id, 6540ie, 6540if, 6540ig, 6540ih, 6540ii, 6540ij, 6540ik, 6540il, 6540im, 6540in, 6540io, 6540ip, 6540iq, 6540ir, 6540is, 6540it, 6540iu, 6540iv, 6540iw, 6540ix, 6540iy, 6540iz, 6540ja, 6540jb, 6540jc, 6540jd, 6540je, 6540jf, 6540jg, 6540jh, 6540ji, 6540jj, 6540jk, 6540jl, 6540jm, 6540jn, 6540jo, 6540jp, 6540jq, 6540jr, 6540js, 6540jt, 6540ju, 6540jv, 6540jw, 6540jx, 6540jy, 6540jz, 6540ka, 6540kb, 6540kc, 6540kd, 6540ke, 6540kf, 6540kg, 6540kh, 6540ki, 6540kj, 6540kk, 6540kl, 6540km, 6540kn, 6540ko, 6540kp, 6540kq, 6540kr, 6540ks, 6540kt, 6540ku, 6540kv, 6540kw, 6540kx, 6540ky, 6540kz, 6540la, 6540lb, 6540lc, 6540ld, 6540le, 6540lf, 6540lg, 6540lh, 6540li, 6540lj, 6540lk, 6540ll, 6540lm, 6540ln, 6540lo, 6540lp, 6540lq, 6540lr, 6540ls, 6540lt, 6540lu, 6540lv, 6540lw, 6540lx, 6540ly, 6540lz, 6540ma, 6540mb, 6540mc, 6540md, 6540me, 6540mf, 6540mg, 6540mh, 6540mi, 6540mj, 6540mk, 6540ml, 6540mm, 6540mn, 6540mo, 6540mp, 6540mq, 6540mr, 6540ms, 6540mt, 6540mu, 6540mv, 6540mw, 6540mx, 6540my, 6540mz, 6540na, 6540nb, 6540nc, 6540nd, 6540ne, 6540nf, 6540ng, 6540nh, 6540ni, 6540nj, 6540nk, 6540nl, 6540nm, 6540nn, 6540no, 6540np, 6540nq, 6540nr, 6540ns, 6540nt, 6540nu, 6540nv, 6540nw, 6540nx, 6540ny, 6540nz, 6540oa, 6540ob, 6540oc, 6540od, 6540oe, 6540of, 6540og, 6540oh, 6540oi, 6540oj, 6540ok, 6540ol, 6540om, 6540on, 6540oo, 6540op, 6540oq, 6540or, 6540os, 6540ot, 6540ou, 6540ov, 6540ow, 6540ox, 6540oy, 6540oz, 6540pa, 6540pb, 6540pc, 6540pd, 6540pe, 6540pf, 6540pg, 6540ph, 6540pi, 6540pj, 6540pk, 6540pl, 6540pm, 6540pn, 6540po, 6540pp, 6540pq, 6540pr, 6540ps, 6540pt, 6540pu, 6540pv, 6540pw, 6540px, 6540py, 6540pz, 6540qa, 6540qb, 6540qc, 6540qd, 6540qe, 6540qf, 6540qg, 6540qh, 6540qi, 6540qj, 6540qk, 6540ql, 6540qm, 6540qn, 6540qo, 6540qp, 6540qq, 6540qr, 6540qs, 6540qt, 6540qu, 6540qv, 6540qw, 6540qx, 6540qy, 6540qz, 6540ra, 6540rb, 6540rc, 6540rd, 6540re, 6540rf, 6540rg, 6540rh, 6540ri, 6540rj, 6540rk, 6540rl, 6540rm, 6540rn, 6540ro, 6540rp, 6540rq, 6540rr, 6540rs, 6540rt, 6540ru, 6540rv, 6540rw, 6540rx, 6540ry, 6540rz, 6540sa, 6540sb, 6540sc, 6540sd, 6540se, 6540sf, 6540sg, 6540sh, 6540si, 6540sj, 6540sk, 6540sl, 6540sm, 6540sn, 6540so, 6540sp, 6540sq, 6540sr, 6540ss, 6540st, 6540su, 6540sv, 6540sw, 6540sx, 6540sy, 6540sz, 6540ta, 6540tb, 6540tc, 6540td, 6540te, 6540tf, 6540tg, 6540th, 6540ti, 6540tj, 6540tk, 6540tl, 6540tm, 6540tn, 6540to, 6540tp, 6540tq, 6540tr, 6540ts, 6540tt, 6540tu, 6540tv, 6540tw, 6540tx, 6540ty, 6540tz, 6540ua, 6540ub, 6540uc, 6540ud, 6540ue, 6540uf, 6540ug, 6540uh, 6540ui, 6540uj, 6